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Technical Paper 369

DEPARTMENT OF COMMERCE
HERBERT HOOVER, SECRETARY
BUREAU OF MINES
D. A. LYON, ACTING DIRECTOR

MECHANICAL SAFEGUARDS IN ROTARY DRILLING

BY

H. C. MILLER

PRICE 10 CENTS
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MECHANICAL SAFEGUARDS IN ROTARY DRILLING

By H. C. Muller

INTRODUCTION

VALUE OF MECHANICAL SAFEGUARDS

Men working about machinery are exposed more or less to danger, but the hazard is greatly increased where dangerous parts of machinery are unguarded. Many accidents attributed to carelessness of employees could be avoided if the machinery and the dangerous surroundings were made safe. The employer's duty is to protect his workmen from injury so far as practicable and by all reasonable means, one of the most important of which is to provide adequate safeguards wherever a hazard exists. An employer, by providing all necessary safeguards and safety devices, teaches his men their first lesson in safety, arouses their enthusiasm, and interests them in safe practices. The employee, however, should not consider that guarding machinery ends the hazard. His duty is to be able to distinguish safe from unsafe practices and at all times to give his first attention to his own safety and the safety of his fellow workmen.

Safeguards installed wherever men work should be conveniently arranged so as to interfere as little as possible with the work. They should be neatly made and installed—two factors that are very necessary to induce proper use and care.

As many accidents occur because the safeguards have been removed and not replaced, hinges or some similar means of attachment are advisable for those safeguards that must often be removed to oil, adjust, or repair the machinery which they guard. As repairs are usually made in a hurry, quick and easy removal and replacement of machinery safeguards must be possible. All safeguards must be durable and strong enough to protect the workman not only from falling or running into the machinery but also from flying parts should the machinery break.

All safeguards on the floor of the oil derrick must be strong and rigid enough to withstand blows from swinging casing, drill pipe, drilling tools, and other equipment used in drilling a well. Iron or steel are preferable to other material, although for many purposes and

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in many places wooden safeguards are adequate, simple to make, and efficient though not as durable.

The nation-wide "safety first" movement promotes habits of carefulness and caution. The employer who provides safeguards for all exposed hazards and employs men who are careful will find the percentage of accidents to his employees greatly decreased. Safeguards alone, however, will not entirely prevent accidents, and employer and employee alike should try to promote safe practices and caution where risk is involved.

PURPOSE OF THE REPORT

This is the first technical paper in a series on safety work in oil fields and discusses safeguards used on the rotary draw works, rotary table, and drilling engine in the oil fields of California. Its purpose is to spread information as to methods of care and safeguards used to protect life and limb from the dangers incident to drilling for oil and gas, also to encourage the installation of safeguards at drilling wells so as to reduce machinery hazards to a minimum.

Various safeguards are shown in the text, but when safeguards are built from the drawings given care should be taken that the dimensions are first checked, as the distance between floor and headboards and the diameter of the sprockets differ with different set-ups and makes of machinery.

The Bureau of Mines earnestly invites those interested to offer suggestions and to comment freely on any of the subjects treated.

ACKNOWLEDGMENTS

Acknowledgments are due to the officers, superintendents, and foremen of the various oil companies visited for the information and hearty cooperation given, and especially to L. E. Stephens, shop foreman, Chanslor, Canfield Midway Oil Co., for the use of his negative of a rotary-drive chain guard; to W. H. Hazlette, engineer, Shell Co. of California, for the blue prints and other information furnished; to Arthur Johnson, safety engineer, producing department, Standard Oil Co. (California), for the courtesy extended in showing the writer the various guards and safety appliances used by his company, and to C. C. Scharpenberg and R. A. Donovan, of the same company, for reviewing the manuscript; to A. L. Tietze, superintendent, Standard Oil Co. (California) producing department, Huntington Beach division, for the blue prints of the brake-flange rim guard he designed; to the officials of the Industrial Accident Commission of the State of California, especially J. Wesley Gebb, engineer, T. W. Osgood, assist-

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ant superintendent, E. G. Sheibley, and G. Chester Brown, for reviewing the manuscript, for the many suggestions given, and for the use of several of their photographs; to Roy W. Kelly, manager, Industrial Relations, and L. J. King, of the Associated Oil Co.; to J. L. Glennon, superintendent of safety of the General Petroleum Corporation, and to M. E. Lombardi, of the Pacific Oil Co., for reviewing the manuscript; to J. G. Shumate for preparing the drawings and sketches, and to F. B. Tough, T. T. Read, E. H. Denny, B. O. Pickard, F. C. Gregory, H. C. Fowler, C. P. Bowie, and L. F. Janssen of the Bureau of Mines, for their many suggestions and their assistance in preparing this report.

SAFEGUARDING THE ROTARY DRAW WORKS

Statistics compiled by the writer and published[1] by the Bureau of Mines show that 13½ per cent of the total number of accidents due to machinery at drilling and producing wells are caused by the machinery of the draw works. The number of days actually lost by the oil workers as a result of these accidents represents 21½ per cent of the total number of lost days that can be charged directly to the drilling and producing machinery.

Since many of these accidents can be avoided by installing proper safeguards, it is nothing short of gross negligence for an operator to ask or permit men to work near "wide-open" draw works under his control.

Certainly no operator can say in justice to himself and his employees that he can not afford to install the necessary safeguards to protect life and limb. Oil-well machinery safeguards are relatively simple, are inexpensive to construct and install, and when once installed are an integral part of the draw-works machinery, movable with the drilling outfit from one location to another. The cost of constructing these safeguards is practically a negligible part of the original cost of the drilling machinery and requires virtually no additional operation and maintenance charge.

Hazards of the unguarded rotary draw works are: 1, Low-gear drum drive-chain and sprockets; 2, high-gear drum drive-chain and sprockets; 3, engine drive-chain and sprockets; 4, brake flange-rims; 5, rotary drive-chain and sprockets (shaft-driven rotary); 6, projecting keys in ends of line shaft; 7, drill drive-chain and sprockets (chain-driven rotary); 8, pinion shaft to rotary table (shaft-driven rotary); and 9, bevel gears and pinion (shaft-driven rotary).

[1] Miller, H. C., Industrial accidents in the California oil fields: Reports of Investigations, Bureau of Mines, Serial 2557, December, 1923, 22 pp.

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SAFEGUARDING THE LOW-GEAR DRUM DRIVE-CHAIN AND SPROCKETS

HAZARDS

Drillers have for many years recognized the danger should the low-gear drum drive-chain break, and, in breaking, whip sideways and foul the brake lever. To prevent such accidents they have made safeguards of material usually found around the derrick. One still finds at many drilling wells a crude or makeshift guard quickly put up with little regard for the strain it may have to bear.

The 6 by 6 inch wooden draw-works brace at the driller's end of the draw works was utilized as a part of the earlier types of low-gear drum drive-chain and sprocket safeguard. This brace was placed directly in line with the sprockets and chain in front of the draw works. To keep the driller's fingers and hands from getting pinched or caught between the sprockets and chain, a 1 by 12 inch board 3 to 5 feet long was nailed against the driller's side of the brace. This 1-inch board, however, will not prevent a breaking chain from flying out and possibly injuring those on the derrick floor. The writer has noted several accidents in which breaking low-gear drum drive-chains split these thin boards, whipped sideways, and injured drillers. Many stands of pipe and tubing have been dropped and workers on the derrick floor injured when a breaking chain fouled the brake lever. The driller will naturally release the brake lever when his hand or arm is struck by a breaking chain, and even though he may endeavor to check the descent of the pipe or tools by applying the lever, the interference of the broken chain wrapped around the lever or wedged between it and the draw-works brace may prevent him doing so.

Belting instead of the 1-inch boards can not be recommended. It may effectively keep out hands and fingers, but the right kind of a blow by a breaking chain will rip and tear it. Something more sturdy than boards or belting is required as a guard on the driller's side of the low-gear chain and sprockets.

DEVICES USED

Many operators bolt or otherwise securely fasten a plate of steel against the driller's side of the 6 by 6 inch wooden draw-works brace. This plate is usually one-eighth to one-fourth inch thick, 12 inches wide, and 5 to 6 feet long, and completely covers the driller's side of the sprockets and chain. Guards of this type are adequate, efficient, relatively cheap to construct, and are favored by many operators and safety engineers.

The more common practice, however, is to make the entire guard of steel. In some installations the timber draw-works brace is replaced with a steel brace that also acts as a guard. In others the wooden

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brace is retained and a steel guard, a unit by itself, is fastened over the sprockets and chain.

A metal guard for the low-gear drum drive-chain and sprocket replacing the usual timber brace of the draw works is shown at *a* in Figure 1. This guard is made from a piece of 8¼-inch casing about 8 feet long, cut in two lengthwise. A plate of steel one-fourth inch thick, 12 inches wide, and from 6 to 7 feet long is welded to the side of the guard next to the driller as a protection for him should the chain break and whip sideways. The upper end of this guard is hinged to the draw-works headboard so that repairs can be made to the chain or sprockets by simply raising the lower end without completely removing the guard from its fastenings. The lower end, which is cut off at an angle so as to rest flat on the floor, is held in

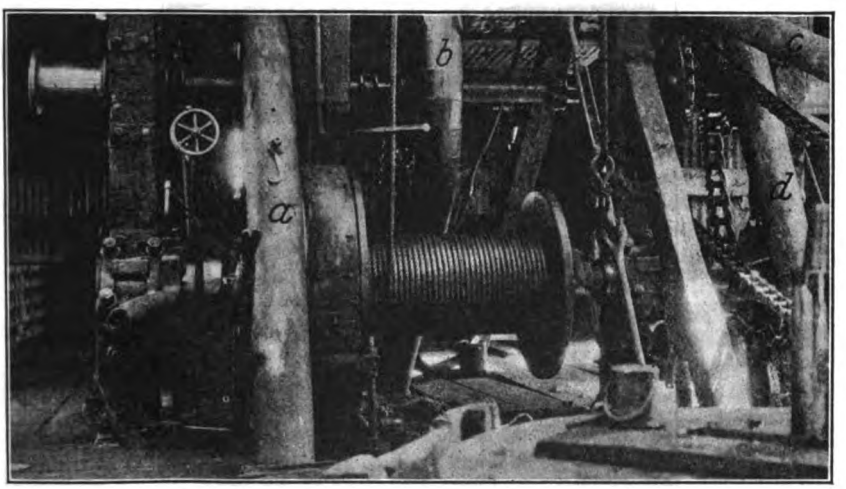

FIGURE 1.—Chain-driven rotary draw works equipped with guards, front view: *a*, Guard over lower-gear-drum drive-chain and sprockets; *b*, guard over engine drive-chain and sprockets; *c*, rotary-table driver chain guard; *d*, guard for high-gear drum drive-chain and sprockets

place by wooden floor wedges. This guard is a substantial brace as well as a protection over dangerous machinery. Operators who have adopted this type of low-gear chain and sprocket guard as standard recommend it highly because it practically does not interfere with workers on the derrick floor, is inexpensive to construct, and can usually be made from scrap casing. As this guard is entirely of steel, it fits in as an integral part of the draw-works machinery and can be moved with it from one location to the next.

Figure 2 gives a side view of a similar guard and shows how completely the steel skirting on the throttle side of the low-gear sprockets and chain cover the hazardous exposure. This protecting flange prevents a breaking chain from fouling the brake lever or

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injuring the driller's legs and feet and eliminates all chances of the driller getting his fingers or hands caught between the chain and sprockets. This guard offers minimum interference with men working on the derrick floor and adequately protects them from low-gear drum drive-chain and sprocket hazards.

GUARDS AT THE REAR OF THE DRAW WORKS

In the past those interested in safety work in the oil fields have considered only exposures at the front of the draw works as dangerous enough to justify guarding. Safety engineers, after thorough study of the causes of accidents at drilling wells, found that the number of injuries caused by the sprockets and chain in the rear of the draw works warranted safeguards there also.

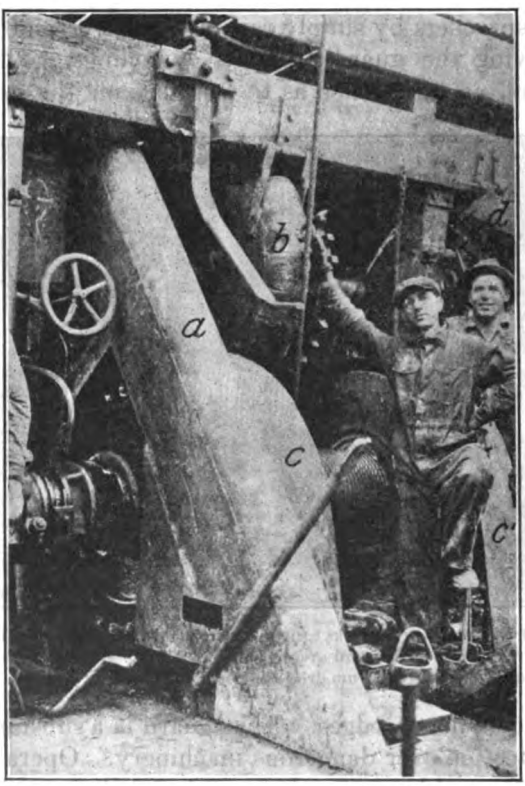

FIGURE 2.—Draw-works guards, side view: *a*, Low-gear drum drive-chain and sprocket guard: *d*, engine drive-chain guard; *c* and *c'*, brake flange-rim guard; *d*, rotary table drive-chain guard

Figure 3 shows the arrangement of a guard that is adaptable to either the shaft-driven or the chain-driven rotary and completely covers the dangerous exposures on both sides of the low-gear drum drive-chain and sprockets. This guard, which is in two sections, completely incases the chain and sprockets and is so designed that it

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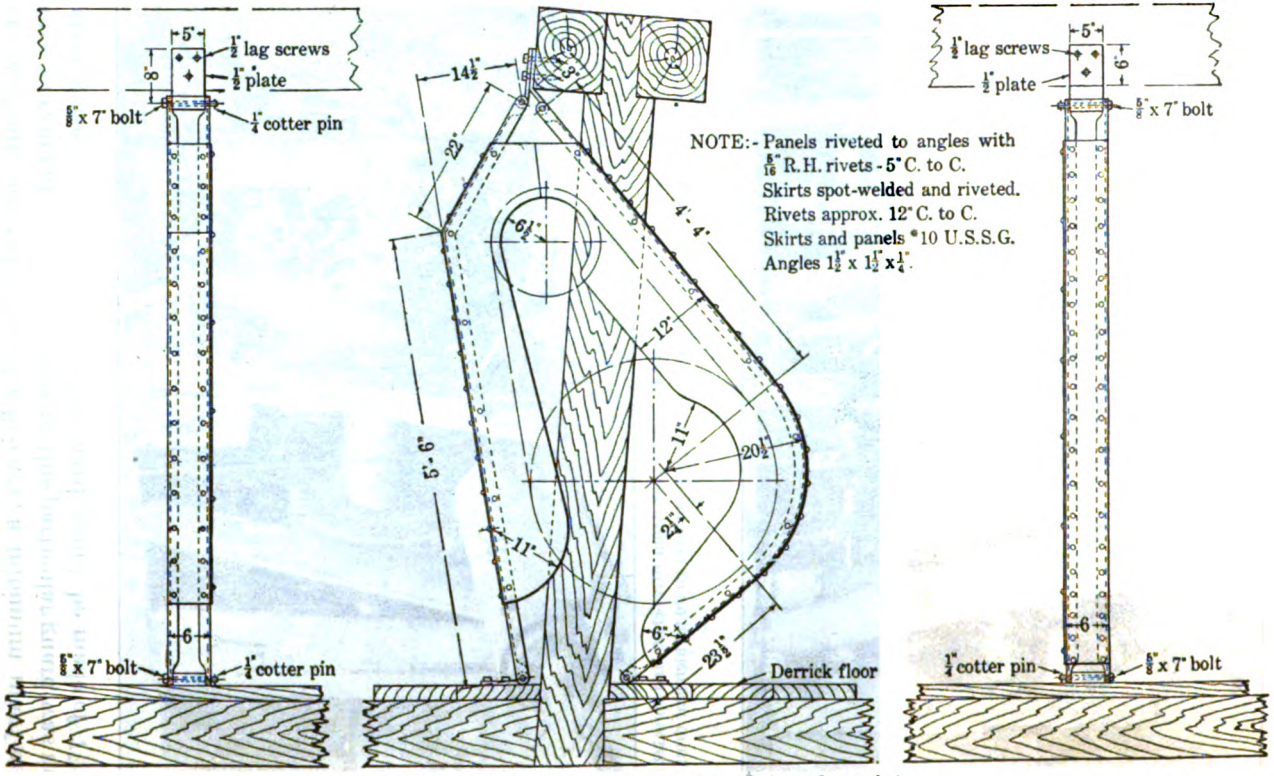

FIGURE 3.—Guard for low-gear drum drive-chain and sprocket

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offers, without any reduction of efficiency, a minimum interference to men working around it. Although this particular guard was made of steel plates and angles, a similar guard could be made of 7⅝ or

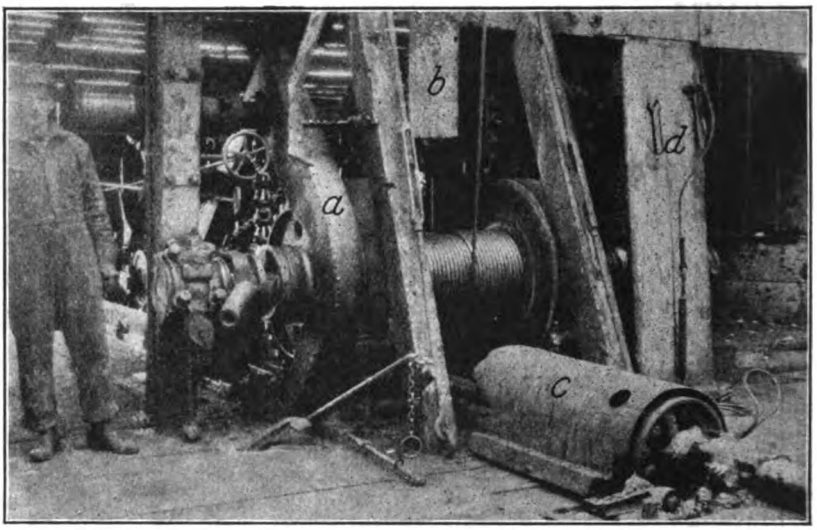

FIGURE 4.—Shaft-driven rotary draw-works guards: *a*, Low-gear drum drive-chain and sprocket guard *b*, engine drive-chain guard; *c*, pinion-shaft guard; *d*, chain and sprocket guard for high-gear drum drive and rotary attachment

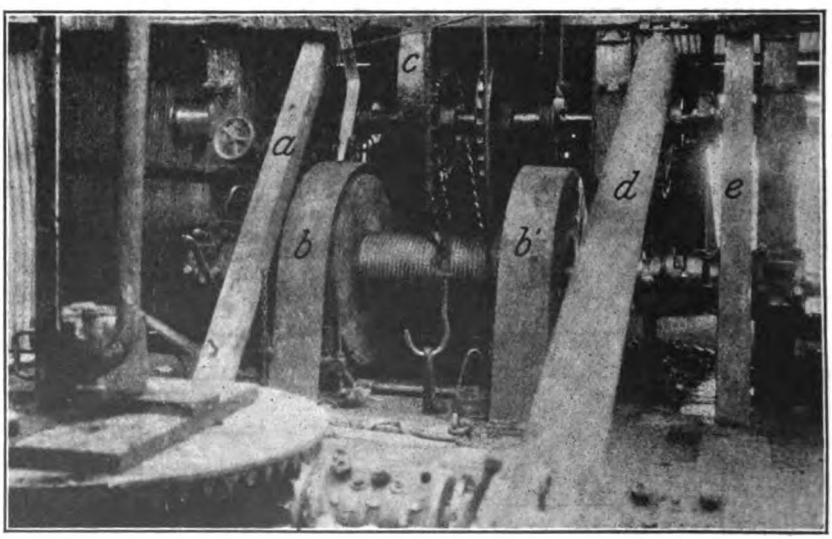

FIGURE 5.—Chain or shaft driven rotary draw-works guards: *a*, Low-gear drum drive-chain and sprocket guard; *b* and *b'*, brake flange-rim guard; *c*, engine drive-chain guard; *d*, table drive-chain guard; *e*, high-gear drum drive-chain and sprocket guard

8¼ inch casing. Both ends of the guard are hinged for easy removal when the chain or sprockets must be uncovered to repair the machinery. The hinge bolts are held in place by cotter pins that are inserted

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in holes drilled through the thread end of the bolts, thus doing away with bolt nuts which often rust tight and require two wrenches to unscrew. The front half of this guard is shown in Figure 4 at *a*.

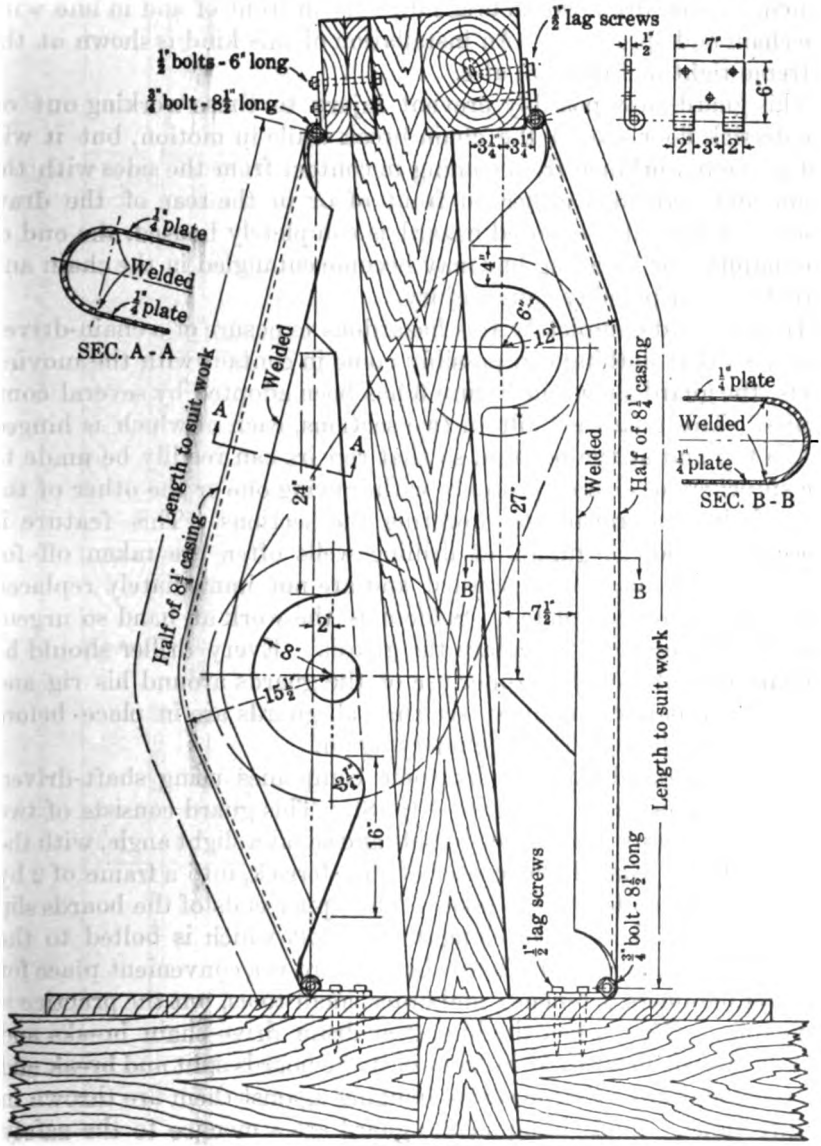

FIGURE 6.—High-gear drum drive-chain and sprocket guard

SAFEGUARDING THE HIGH-GEAR DRUM DRIVE-CHAIN AND SPROCKETS

The hazards at the high-gear drum drive-chain and sprockets are generally considered less than those at the low-gear end of the draw works. Although they are not as frequent, accidents at the high-

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gear end are not uncommon, and provisions should be made to minimize all chances of injury. To protect workmen on the derrick floor from flying pieces of breaking chain many companies place the 6 by 6 inch wooden draw-works brace directly in front of and in line with the chain and sprockets. An installation of this kind is shown at the extreme right of Figure 5, at *e*.

This guard may possibly prevent injury to those working out on the derrick floor should the chain break while in motion, but it will not prevent workmen from coming in contact from the sides with the chain and sprockets either in front of or in the rear of the draw works. Unless this exposed hazard is completely housed, the end of the snapping or breaking line may become entangled in the chain and sprockets and possibly cause injury.

To safeguard completely this hazardous exposure of a chain-driven rotary so that nothing can possibly come in contact with the moving parts, the guard shown in Figure 6 has been adopted by several companies. This guard is built in two sections, each of which is hinged at the top and at the bottom, so that repairs can readily be made to the sprockets or chain by simply withdrawing one or the other of the hinge bolts and raising or lowering the sections. This feature is especially good, as guards at drilling wells often are taken off for repairs to the machinery guarded and are not immediately replaced when repairs are completed. Seldom is the work at hand so urgent that there is no time to replace the guards. Every driller should be held responsible for the proper use of the guards around his rig and should, as a part of his duty, see that all guards are in place before he starts the draw-works machinery again.

A wooden guard adopted by some companies using shaft-driven rotaries is shown at *d* in Figure 4 (p. 8). This guard consists of two 2 by 12 inch boards placed side by side and set at a slight angle, with the lower end out toward the center of the derrick, into a frame of 2 by 4 inch lumber nailed to the floor. The upper ends of the boards slip behind an iron bracket or elongated U bolt which is bolted to the headboard. As shown in Figure 4 this guard is a convenient place for hanging hammers, wrenches, and other small tools, but the practice is dangerous. Often when the high-gear drum drive-chain breaks and strikes this wooden guard in front of it the boards split and break and the tools and any other material hanging against them are thrown in all directions. Tools hung on the guard are a menace to the safety of the men working on the derrick floor.

The failure of the wooden high-gear drum drive-chain and sprocket guard of the shaft-driven rotary to withstand the blow of a breaking chain or to cover completely the hazards exposed led to the development of the all-metal safeguard shown in Figure 7. The front

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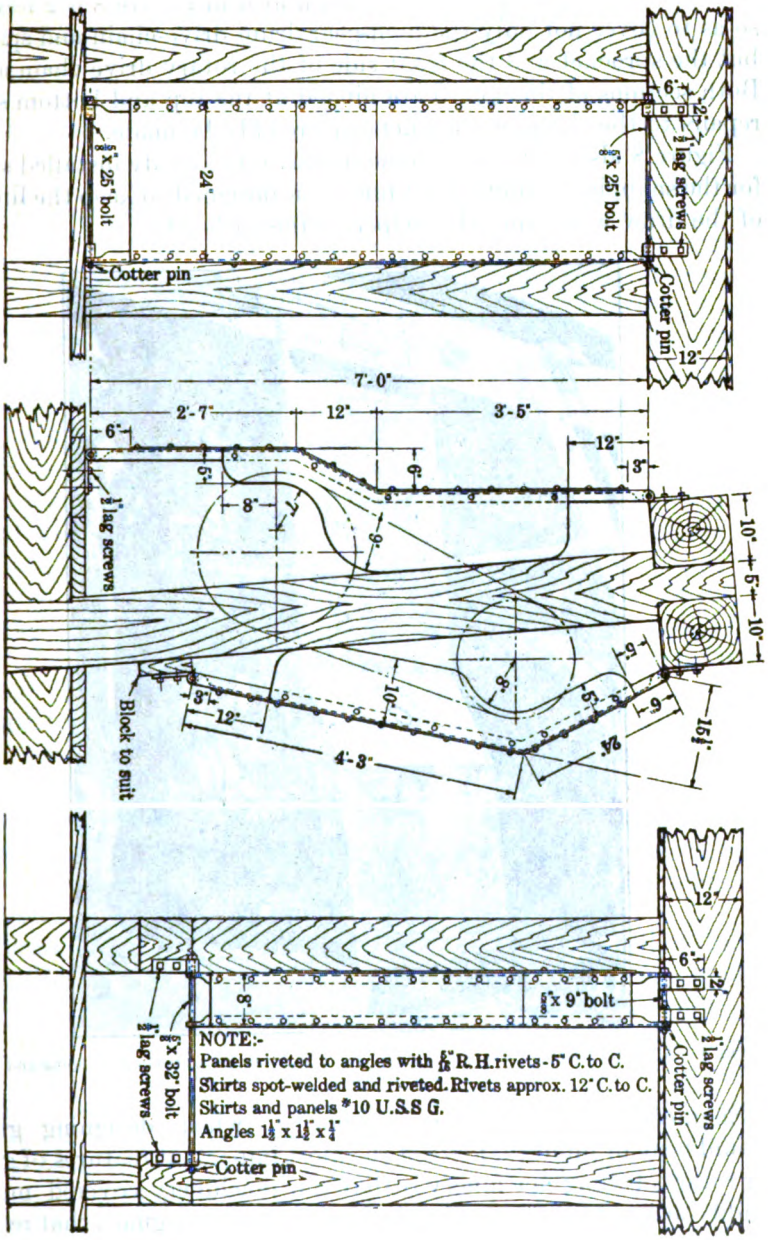

FIGURE 7.—High-gear drum drive-chain and sprocket guard (shaft-driven rotary)

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section of this guard, which is shown at *a* in Figure 8 is 2 feet wide, so as to cover not only the high-gear drum drive-chain and sprockets but the sprocket and the front side of the rotary drive chain as well. Both sections of this guard are hinged at the top and bottom so that repairs to the chain or sprockets can readily be made.

Figure 8 also shows at *b* an inexpensive and easily installed support for the snapping and breaking line; it is designed to keep the line clear of the draw works and the helper at the cathead.

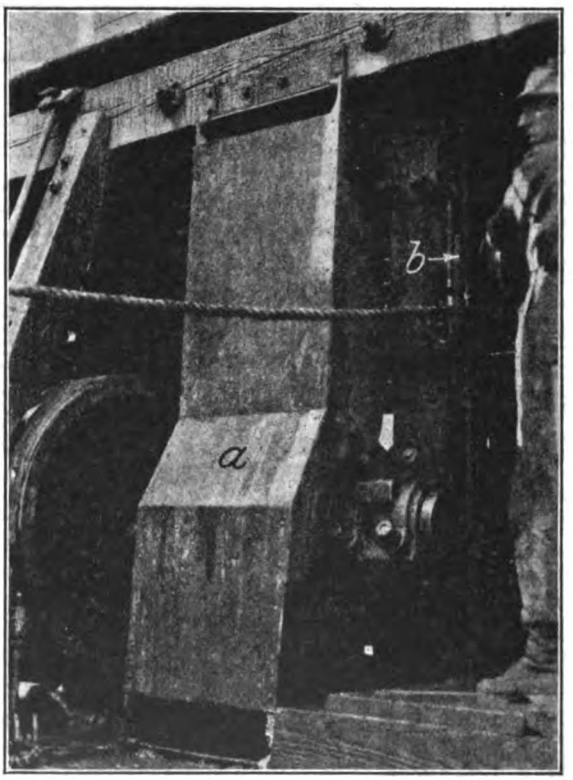

FIGURE 8.—All-metal safeguard shown in Figure 7 (*a*), and device for supporting snapping and breaking lines (*b*)

Engineers and others in authority, when designing guards, should bear in mind that one of the most important features of guards for rotary drilling machinery is that the machinery covered must be readily accessible for examination and repair. A guard that requires two wrenches and several men to remove and later replace it is never popular with the drilling crews. Guards hinged with hinge bolts that can be easily and quickly withdrawn are preferable to permanently attached guards. Hinge bolts fitted with a cotter pin at the thread end are preferable to those on which a bolt nut has to be screwed. The vibrations of the derricks often cause the nuts to fall off allowing

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the hinge bolts to slide out of the hinges, or the nuts rust in place and can not be removed without considerable effort and the use of two wrenches.

SAFEGUARDING THE ENGINE DRIVE-CHAIN AND SPROCKETS

The engine chain and sprockets can be covered so that a breaking chain will not injure the workers on the derrick floor or anyone going underneath the chain in the rear of the draw works with the guard shown at *b* in Figure 1 (p. 5). Figure 9 shows in detail the structural features of this guard. When guards for engine drive-sprockets are built, proper clearance must be carefully allowed because of the different-size sprockets used, so that a chain in slipping a tooth will not wreck the guard. The radius of curvature of this and all other guards illustrated here should be checked against the diameter of the sprockets to be covered, and a clearance of not less than 2½ inches allowed between the outside of the sprocket teeth and the inside of the guard.

The guard shown in Figure 9 is usually made of scrap casing, split in two lengthwise with a cutting torch. The upper end is shaped to conform to the radius of curvature of the drive sprocket by burning out wedge-shaped pieces along each edge, bending the pipe, and welding the edges of the cuts together again. Plates of steel five-sixteenths inch thick are welded on each side of the curved part of the guard to cover the front half of the line-shaft sprocket and its point of contact with the chain. The guard is fastened to the headboard at the top by a pair of hinges. By withdrawal of the hinge bolt the guard can be quickly removed and replaced when necessary. The lower end rests on the engine-base anchor pipe and does not have to be fastened, as lateral movement is limited by the engine-foundation timbers on either side.

The detail of the guard for the upper half of the engine drive-chain shown in Figure 9 is similar to that of the lower guard. The upper part of the guard is a piece of 8¼-inch casing cut in two lengthwise, to both edges of which plates of steel five-sixteenths inch thick are welded. These plates extend the entire length of the casing and are wide at the lower end to cover the space between the upper and lower guards. To prevent a man having his hand or foot cut off by the sharp edges of these plates at their widest part, should the chain tend to drag him into the sprocket, a bar of one-half by 2-inch iron is welded edgewise to the exposed edge on each side. The notch in the lower end of the guard fits over an iron bar 1¼ inches in diameter which has been bent as shown in the detail drawing. This bar holds the guard centrally over the chain and sprocket and gives the

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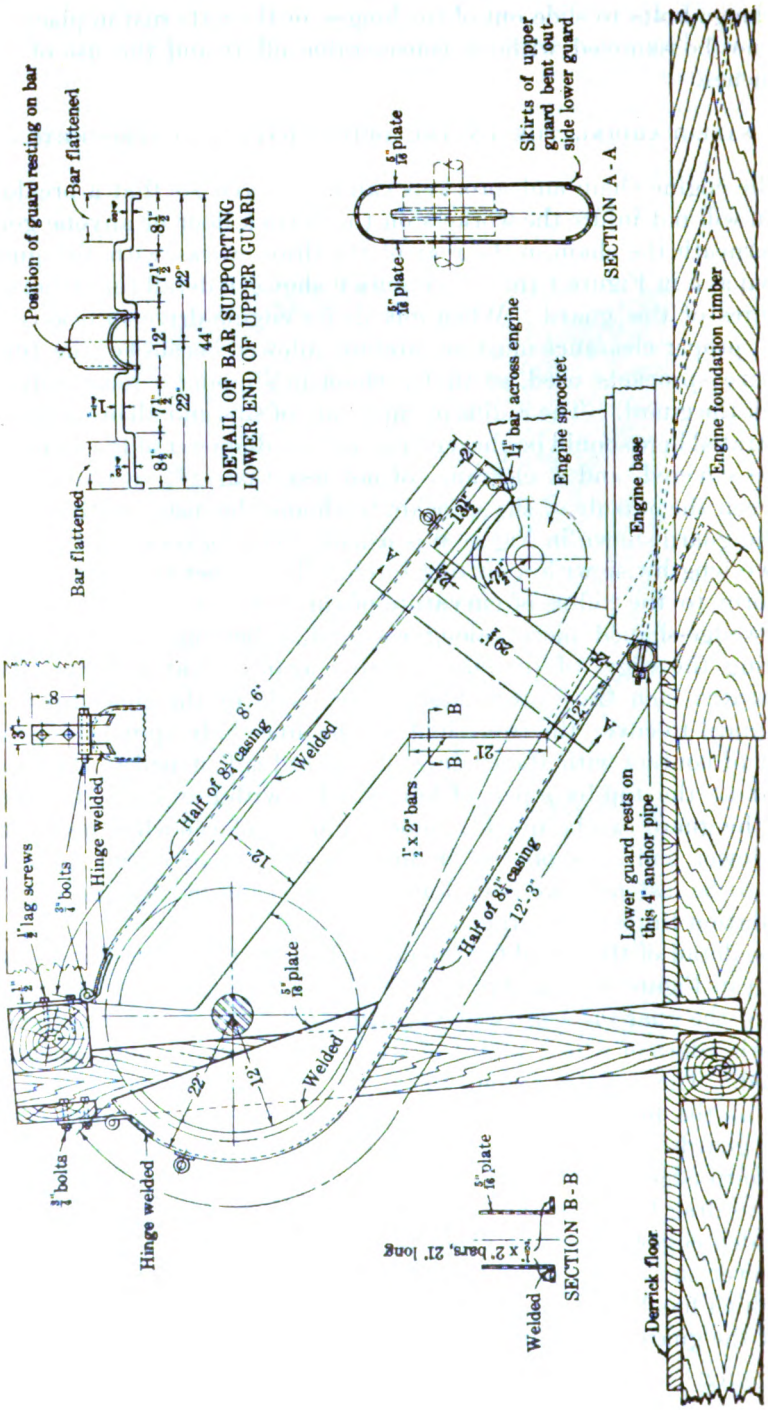

FIGURE 9.—Engine drive-chain and sprocket guard

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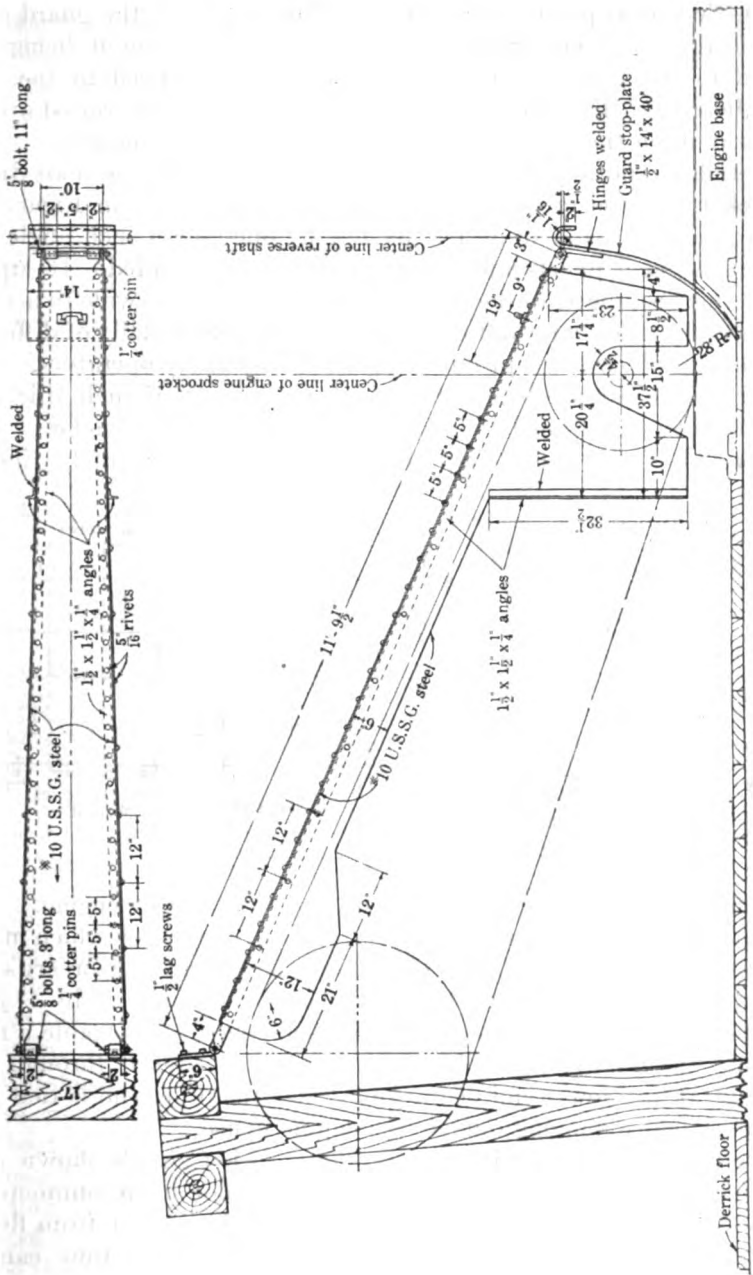

FIGURE 10.—Guard for upper engine drive-chain and sprockets

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eccentric straps plenty of clearance. The weight of the guard resting on this bar is enough to hold the bar in place without being fastened to the engine frame. The upper end is hinged to the rear headboard so that the lower end of the guard can be raised out of the way when the chain is repaired or sprockets are changed.

Details of another type of guard for the engine and line shaft drive-sprocket and the upper engine drive-chain are shown in Figure 10. This guard is made from 1½ by 1½ by one-fourth inch angles, to which the steel panels and skirts are riveted and welded. Its upper end, which is hinged to the rear headboard, is 17 inches wide to accommodate the three line-shaft engine drive-sprockets, usually of different diameters, which are kept on the line shaft by many operators. The lower end is hinged to a curved iron plate one-half inch thick, 14 inches wide, and 40 inches long, bent to a radius of 28 inches. The upper end of this guard stop plate is bent to a radius of $1\frac{1}{16}$ inches

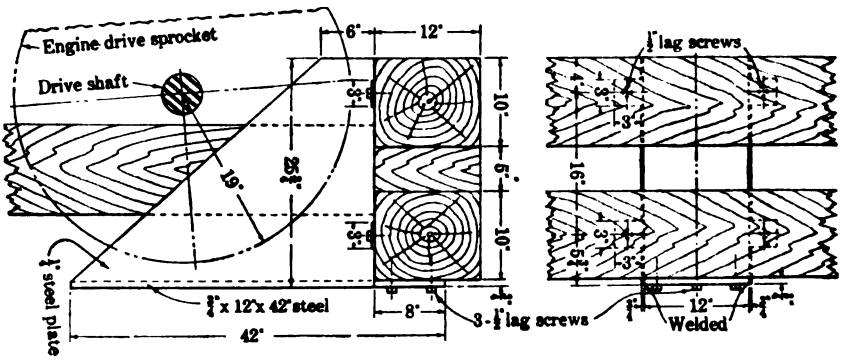

FIGURE 11.—Line-shaft engine drive-sprocket guard

and hooks over the reverse shaft of the twin drilling engine. The sharp edges of the steel skirts on both sides of the guard, which might injure a man, should the drive chain carry him against them, are safeguarded as shown in Figure 10, by riveting or welding 1½ by 1½ by one-fourth inch angles along the exposed edges. To enable a man to raise the guard easily, one end of a rope is fastened through the eye lug at the lower end of the guard and the other end is tied to a counterbalance hanging outside the engine house.

The line-shaft engine drive-chain and sprocket guards shown at *b* in Figure 4 and at *c* in Figure 5 (p. 8) can not be recommended. Although in a measure they would keep a breaking chain from flying out and injuring those at work on the derrick floor, they can be materially improved by welding a skirt or apron on each side, as shown in Figure 9. However, when this type of guard is used some provision must be made to guard the lower drive chain in the rear of the draw works. A wooden or pipe railing on each side of the chain, so constructed that no one can come in contact with the chain, either

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through the panel openings or over the rail, makes a good guard. When such guards are used for the lower chain and a guard like that shown in Figures 9 and 10 is used for the upper chain, the line-shaft engine drive-chain and sprocket guard shown in Figure 11 can be recommended.

SAFEGUARDING THE BRAKE-FLANGE RIMS

CAUSES OF RIMS FAILING

Bursting of the rotary brake-flange rims has been responsible for six recent fatalities and many lost-time accidents in the California oil fields. The intense heat generated by "throwing" on the brakes in checking the rapid descent of the drill stem or string of pipe produces stresses that expand the rim, thus weakening the drum flanges so much that many flanges burst. Other contributing causes reported by the engineers of the industrial accident commission of the State of California[2] are: Riveting the brake flange to the hoisting drum at the derrick instead of in the shop; weak or loose rivets; unequal contraction and expansion of the brake flange; crystallization; unequal pressure of the brake band; too sudden application of the brake; and faulty construction and defective materials.

A study of several burst brake-flange rims showed that they had become weakened through alternate expansion and contraction. At first these temperature stresses produce invisible hair checks in the rim of the brake flange; these checks grow larger and larger with every change in temperature until they become so large and so numerous that the weakened flange fails. For this reason brake-flange rims that have been long in service fail more frequently than those that have been in use only a short time.

PRECAUTIONS RECOMMENDED

Brake-flange rims "blow up" without warning, and the men on the derrick floor have no time to seek safety from the flying particles that are thrown fanwise over the derrick floor. Drillers should examine their brake-flange rims at frequent intervals and replace those showing the slightest fracture or flaw. Those with weak or loose rivets should be sent to the shop for repair, as derrick repairs at best should not be trusted. Brake bands should be carefully adjusted to pull equally on each brake rim and care should be taken that the brake is not applied too suddenly to a rapidly revolving rotary drum.

In the California oil fields the six recent fatalities due to bursting brake flanges were caused by the failure of cast-iron rims. Cast-steel

[2] Gebb, J. Wesley, Guards for brake flanges of rotary hoisting drums: California Safety News, vol. 8, March, 1924, p. 3.

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brake flanges are now being built for hoisting drums used in deep drilling, and, although they stand up better under heavy duty they are also subject to temperature stresses. The writer's attention was recently called to the failure of a cast-steel brake flange by a crack that developed in each of the reinforcing ribs on the inside of the flange. This rim did not burst, but it is wise and even necessary to use the same safeguarding measures over cast-steel as over cast-iron brake flanges. Cast-steel brake flanges also wear the brake lining excessively, and for this reason some operators have again reverted to the use of cast-iron rims.

PRESSED-STEEL BRAKE FLANGES

Hoisting drums with pressed-steel brake flanges have been built recently, and are now being tested to prove that such flanges will not burst or wear out the brake lining any quicker than do cast-iron brake flanges. So much faith has been placed in these pressed-steel brake flanges that the industrial accident commission of the State of California has temporarily exempted several operators from placing guards over them. Operators are assisting the commission's engineers in keeping a careful check on the ability of these brake flanges to stand up under heavy duty and to detect any weakness which may develop. If these pressed-steel flanges ultimately are shown to eliminate the hazards due to bursting brake flanges, a revision of that part of the safety orders[3] regarding safeguarding all rotary brake drum flanges will no doubt be requested by the operators. To encourage the construction of machinery which does not have to be guarded is commendable in accident prevention work.

METAL GUARDS

Excessive speed in lowering drill pipe, casing, and tubing should be discouraged and the centrifugal force of the whirling brake flange kept to a safe limit in order to avoid injury, possibly fatal, to those working on the derrick floor. Whether cast-iron or cast-steel rims are used no rotary draw works is completely safeguarded against the destruction of life and limb without a set of adequate metal guards over the rims of the brake flanges.

Figure 12 illustrates a metal guard designed to stop flying fragments of a bursting rim. As shown at *b* and *b'* in Figure 5 these guards cover the rims of the brake flanges very effectively. Several months after the first set of these guards was installed, a rim safeguarded by one of them burst. Previously this accident would undoubtedly have meant a serious injury or possibly a fatality, but the guard, although

[3] Industrial Accident Commission of the State of California, General Petroleum Industry Safety Orders for Drilling and Production, March, 1924, p. 15.

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slightly bent out of shape, remained intact and prevented the broken fragments from striking those at work on the derrick floor.

When guards of this description are installed they should be firmly attached to the floor or to the floor beams underneath; otherwise they will tear away from their fastenings and will not hold back broken fragments when the brake rim bursts. Bolting the guards to steel plates or angles on the under side of the derrick floor is advisable.

The plates or angles should be large enough to spread the upward pull of the bolts over a large area and preferably against the underside of the floor timbers.

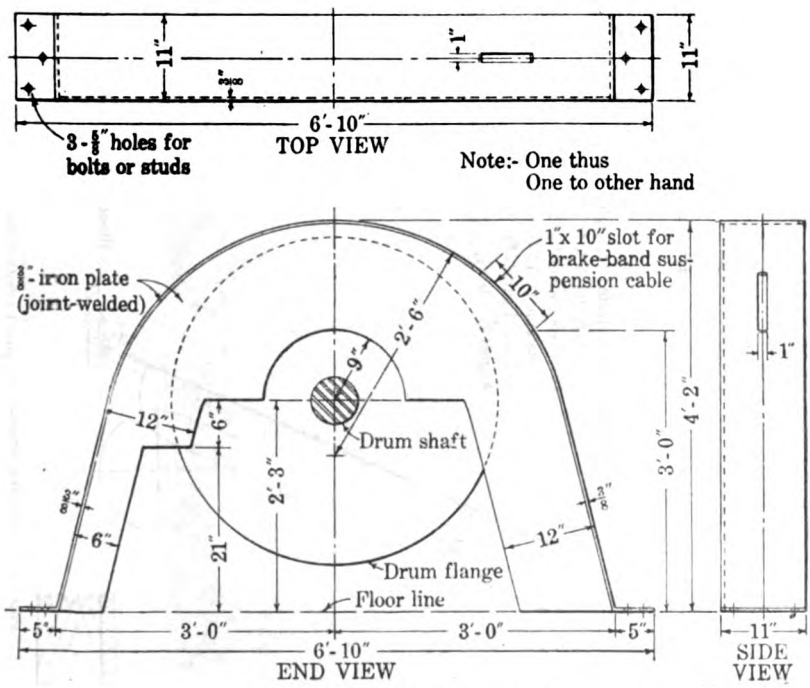

FIGURE 12.—Guard for brake-flange rim

SAFEGUARDING THE ROTARY-DRIVE CHAIN AND SPROCKETS OF A SHAFT-DRIVEN ROTARY

In discussion of the safeguards over the high-gear drive chain and sprockets of a shaft-driven rotary (p. 9) mention was made that the wide guard served a double purpose by covering both the high-gear drum drive and the rotary drive-chain and sprocket exposures in front of the draw works.

Figure 13 shows one method of guarding the drive chain and sprockets in the rear of the draw works. This safeguard is made of 1½ by 1½ by one-fourth inch angles and 10-gauge steel and is hinged at both

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the top and bottom to facilitate removal of the chain or sprockets for repair. The hinge bolts are drilled at the thread end for a cotter pin of one-quarter-inch diameter, which likewise facilitates the easy removal of the safeguard.

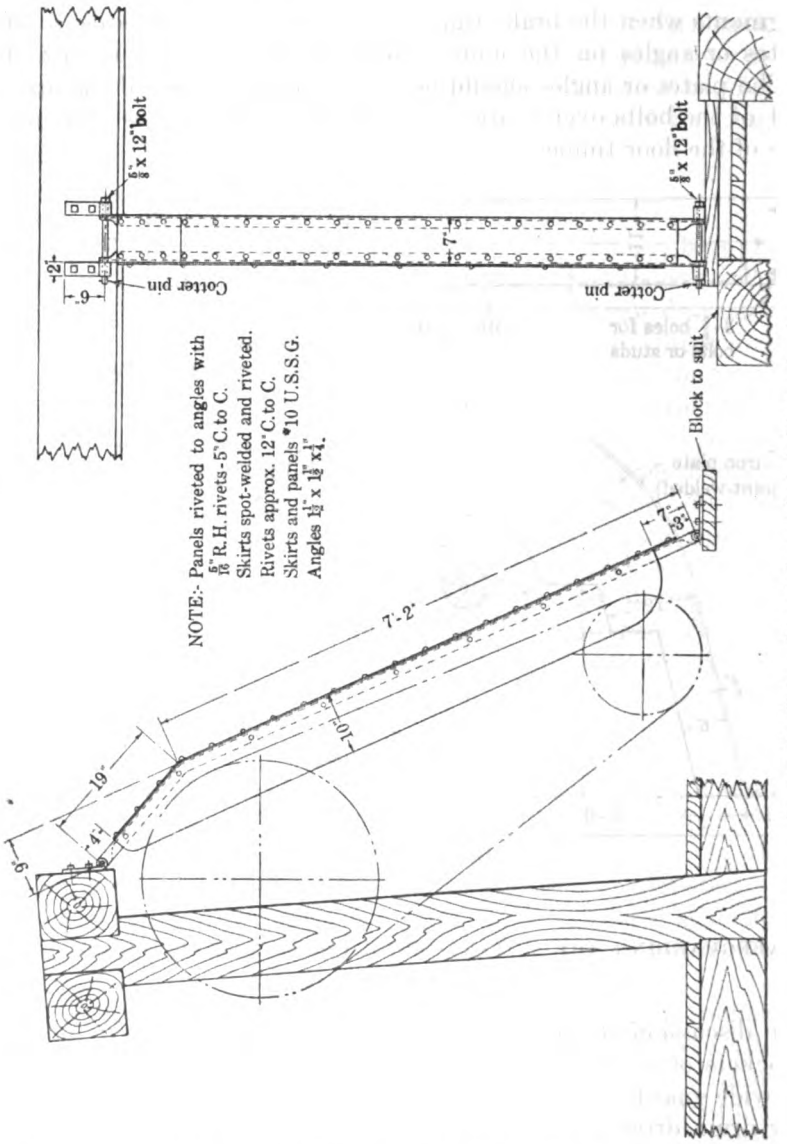

FIGURE 13.—Rotary drive-chain guard (shaft-driven rotary)

Companies having a surplus of old 7⅝ or 8¼ inch casing or pipe about 8 inches in diameter can follow the general suggestions shown in Figure 13 and make, at slight expense, adequate and efficient guards from such scrap.

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SAFEGUARDING THE ENDS OF THE LINE SHAFT

Protruding keys in the ends of the line shaft are dangerous, chiefly because they are at the catheads at such a height that a man is liable to injure his head while working the catheads or when walking through the narrow passageway between the ends of the drive shaft and the corners of the derrick. Injuries to hands and arms are also frequent around catheads when the shafts or keys project. To prevent such injuries the cathead keys should be driven flush, sawed

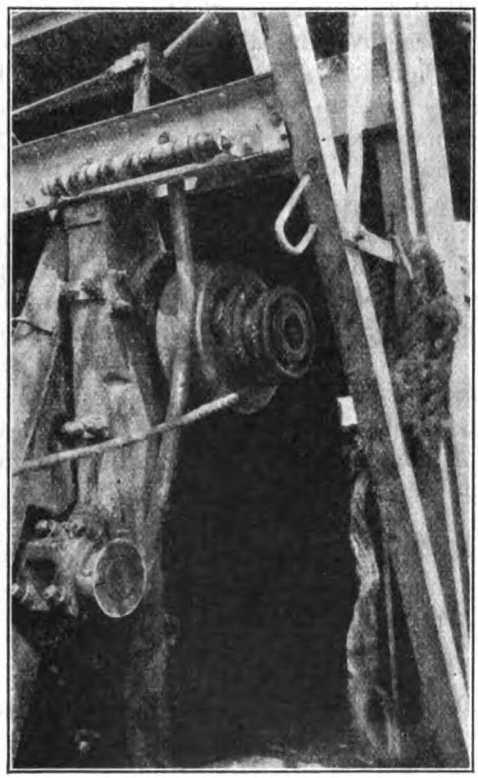

FIGURE 14.—Clutch type of cathead used at drilling wells

off even with the ends of the line shaft or covered with a thimble or other suitable protector fastened to the ends of the line shaft by countersunk cap screws

Accidents at the catheads are especially numerous in new fields where wells are put down in a hurry. Haste due to attempts to break records for speed in drilling or to reach the oil sand ahead of the other fellow is one of the greatest enemies of safety. Work at a cathead has always been dangerous because the starting, stopping, and rotation of the cathead are controlled by the driller at the opposite end of the draw works and not by the man holding the end of

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the snapping or breaking line. The latter can not stop the rotation of the cathead should his fingers or arm get caught in the line or between the line and the cathead; the command to stop must go from him to the driller. The noise made by the drilling engine and the sprocket chains often makes it difficult for the driller to hear the voice of the cathead man and frequently his calls or signals to stop are misunderstood or not heard at all.

Several attempts have been made to build catheads with individual control, so that their manipulation would be controlled by the cathead man. With further experimenting and some changes in the present designs, a practical cathead and clutch will be devised. The cathead shown in Figure 14, although remotely controlled, overcomes many of the objections to the old style of cathead. The snapping or breaking line is attached to a dog within the clutch housing and winds and unwinds on the cathead under the control, through levers and a clutch, of the driller standing at the far side of the draw works. The cathead man does not work at the cathead and therefore can not get caught in the rope or between the rope and the cathead. Neither will he receive injuries should the line foul on the cathead, nor can he be hit when tongs under strain break or unlatch from the pipe and swing toward the cathead. Such accidents frequently occur when there is no safety cable on the tongs or when the cable breaks. The men on the derrick floor have a chance to stand away from the tongs and tong line, out of danger, when this cathead is used.

When the cathead is to be used for special work, such as bringing in a joint of pipe or raising tools and materials in the derrick with the cat line, the snapping line is disconnected. The cathead man then uses this cathead as he used the older types that are keyed on the line shaft.

SAFEGUARDING THE ROTARY TABLE DRIVE-CHAIN AND SPROCKETS

HAZARDS

Wherever drive chains are exposed a hazard exists, but few so great as that of the rotary table drive-chain of a chain-driven rotary. Many men have been seriously and fatally injured between the unguarded sprockets and drive chain. Some have been injured when crawling under, between, or over the drive chain, or by being struck by a breaking chain or the parts of it. Others have suffered serious injuries to their feet and toes when standing too near a slapping chain. Perhaps the most common accidents happen to members of the drilling crew who accidently run or are forced into the unguarded chain during their work on the derrick floor.

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DEVICES USED

Figure 15 illustrates a type of safeguard for the rotary table drive-chain in which advantageous use was made of the sprocket guard furnished by the manufacturer of the rotary equipment. The upper chain guard is made from a piece of 6¼-inch casing cut in two lengthwise, then cut into three parts and welded together again so as to give it a curve conforming closely to the catenary curve of the chain. The upper end of this guard, which unfortunately is not shown in the illustration, was cut with the cutting torch so as to leave a piece of metal 3 inches wide and 8 inches long projecting beyond the end of the pipe. This strip was then bent to make a hook pointing downward which rests in a square U socket made out of three-eighths by 4

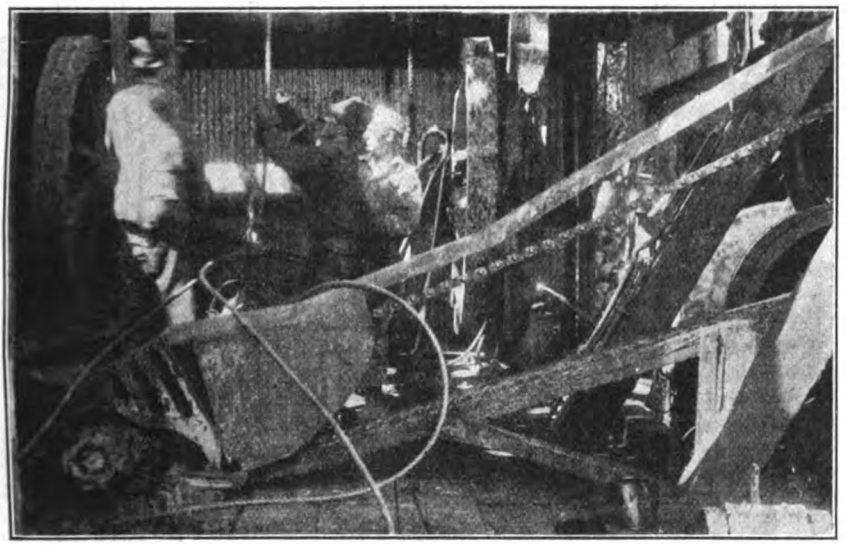

FIGURE 15.—Guarded rotary table drive-chain and sprockets

inch iron bolted by four one-half-inch bolts to the outer side of the headboards. As there are no nuts to loosen or bolts to take out, this guard can be removed and replaced in a very few moments. A 2 by 12 inch board extending from the rotary table frame to the draw works, supported on 2 by 12 inch legs and braced with short pieces of 2 by 4 inch lumber, supports the lower chain.

A sure way to keep men from crawling between the upper and lower parts of the chain would be to increase the width of the steel skirts on each side of this safeguard at least 2 feet and to carry this width down to the inclined plank or lower chain guard.

Figure 16, a drawing of a rotary table drive-chain and sprocket guard, shows how points of contact of the chain with the sprockets are covered, which minimizes the chance of men being injured through contact with the chain. The guard shown is made from 10-inch

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casing. The edges of the steel skirts toward the draw works are bent out so that the chain will not catch on these edges and injure the guard or the chain itself or injure a worker should he be pulled against the sharp edges by the moving chain.

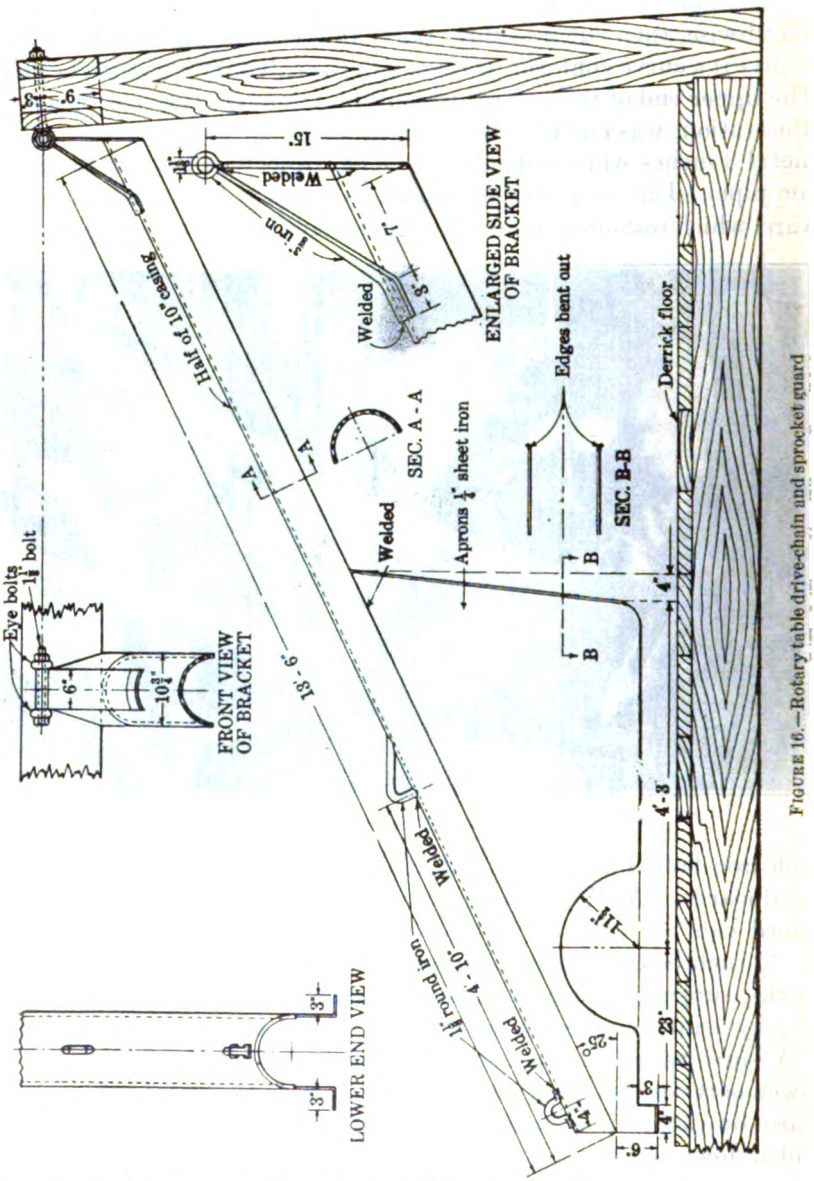

FIGURE 16.—Rotary table drive-chain and sprocket guard

Angles and plate steel can be used just as well as casing to make this guard, although many companies find the use of old casing, if available, is more economical.

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To repair the chain or to do any work with which the guard would interfere the lower end can be lifted out of the way by means of the catline without detaching the guard from its fastenings and lowered again when the work at hand is finished.

The safeguard shown in Figure 17 illustrates a method used to guard the rotary table drive-chain and sprockets completely so that a worker crawling through or under or jumping over them can not possibly come in contact with the chain. This guard has been tried out successfully and is now standard equipment with at least one oil company in California. The designer says[4] that "the guard is made from scrap 11⅝-inch casing mounted on strap irons of 1 by 3 inch stock which are bolted to the floor. The pipes fully cover the chains, so that men may crawl through, under, and over

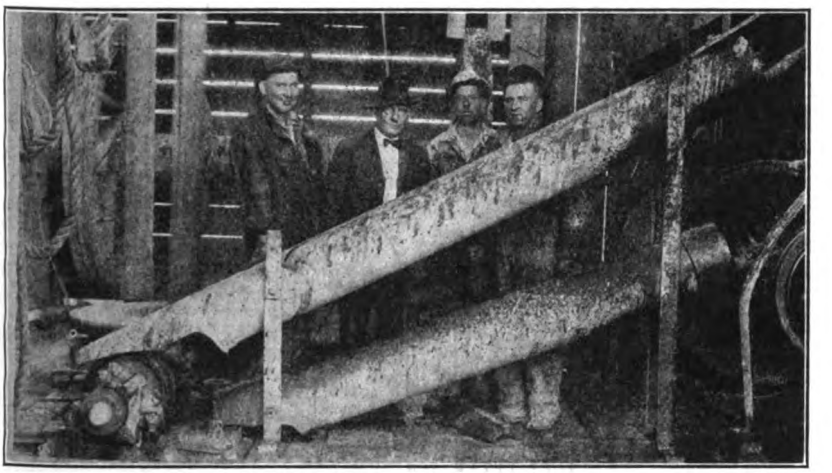

FIGURE 17.—Excellent rotary table drive-chain guard

without any danger whatever. On account of the large diameter of the pipe used, no trouble is experienced in passing the chain through it. There is very little slapping of the chain on the pipe."

GUARDING THE LINE-SHAFT TABLE DRIVE-SPROCKET

Although the guards shown in Figure 15, Figure 16, and Figure 17 completely cover the otherwise exposed hazards of the line-shaft rotary table drive-sprocket, pinion-shaft sprocket, and the drive chain between, provision should also be made to safeguard the line-shaft rotary table drive-sprocket in the rear of the draw works. Figure 18 shows one method of doing this. The guard is made from a section of 8¼-inch casing, cut in two lengthwise and bent to con-

[4] Stephens, Lewis E., Letter to Industrial Accident Commission: California Safety News, vol. 7, No. 8, August, 1923, p. 13.

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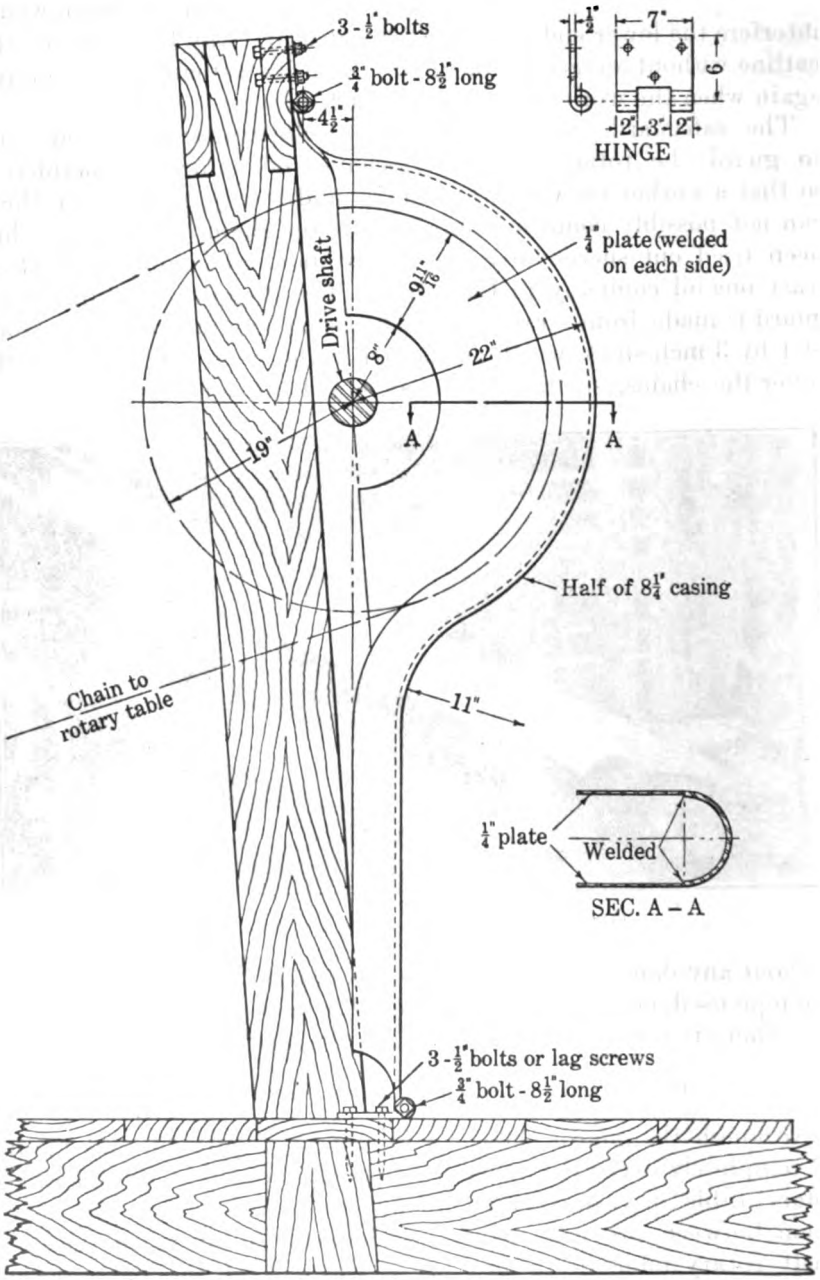

FIGURE 18.—Rear guard over rotary table drive-sprocket

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form to the radius of curvature of the line-shaft rotary table drive-sprocket. Skirts or plates of quarter-inch steel are welded to each side of the casing so as to cover completely that half of the sprocket which is exposed in the rear of the draw works. To expedite repair of the chain or sprockets covered, this guard is hinged at its upper and its lower end.

SAFEGUARDING THE PINION SHAFT OF THE SHAFT-DRIVEN ROTARY

The absence of the rotary table drive-chain in the shaft-driven rotary eliminates one of the greatest hazards to operators of the

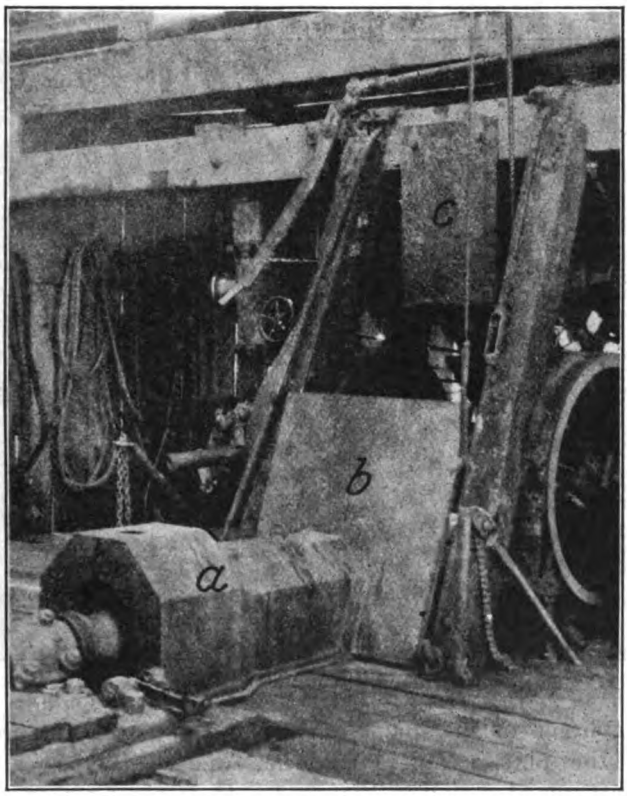

FIGURE 19.—Shaft-driven rotary guards: *a*, Pinion-shaft guard; *b*, drum guard; *c*, engine drive-sprocket guard

chain-driven rotary and to workmen on the derrick floor. However, a slightly different hazard exists in the pinion shaft that spans the floor of the derrick between the rotary table and the draw works of a shaft-driven rotary. As this shaft is usually about 6 inches above the derrick floor, is directly across the path of travel in front of the draw works, and revolves rapidly when drilling is in progress, some means must be taken to prevent a worker from coming in contact with it and the couplings.

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As shown at *c* in Figure 4 (p. 8), a semicircular guard of sheet steel is used. This guard is made of three-sixteenths-inch steel. It is usually reenforced at the floor line with 1½ by 1½ by one-fourth inch steel angles, but the one illustrated is strengthened by a piece of 3 by 3 inch timber fastened to each edge.

Figure 19 shows *a* an improved type of pinion-shaft guard. The square plate *b* which is welded around the guard at the drawworks end, prevents a worker from falling or being thrown into the drum and perhaps being entangled by the drilling line. The entire guard is made of 10-gauge steel plate welded as shown and reenforced with 1½ by 1½ by one-fourth inch angles at the floor line, at the

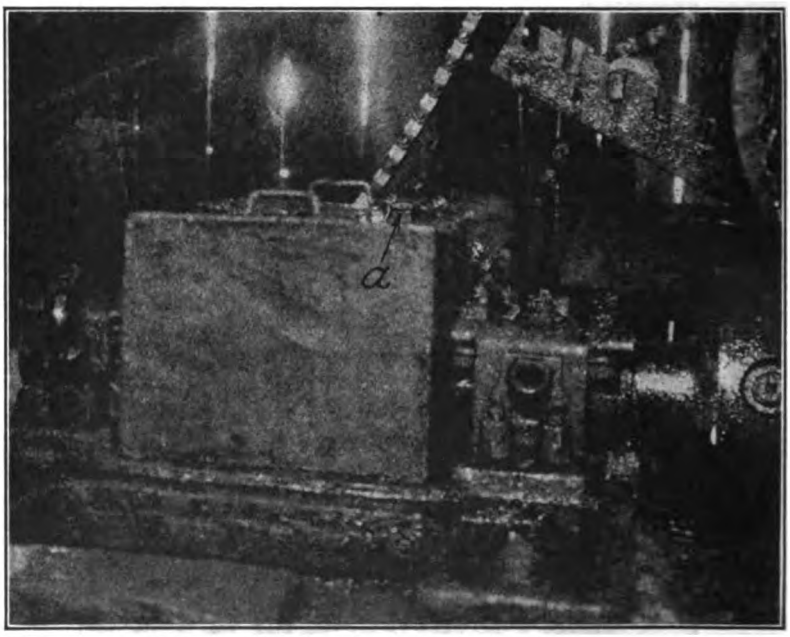

FIGURE 20.—Guard over bevel gears of a shaft-driven rotary

point of contact of the shaft guard and the plate, and around the edges of the plate. This guard has many advantages over the pinion-shaft guard shown in Figure 4. It is stronger, men are not so apt to step on it and slide off, and it is heavy enough in itself to remain in position without having to be bolted or otherwise attached to the floor.

SAFEGUARDING THE BEVEL GEARS OF THE SHAFT-DRIVEN ROTARY

Exposed gears, no matter where located, are dangerous and, unless they are properly inclosed in a metal casing or otherwise securely guarded, are a constant hazard to workmen. They must be oiled at

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intervals and adjusted often. It is always a good rule to shut down the machinery while gears are being oiled or adjusted or the bearings taken up, but there are times when proper adjustment requires the machinery to be running.

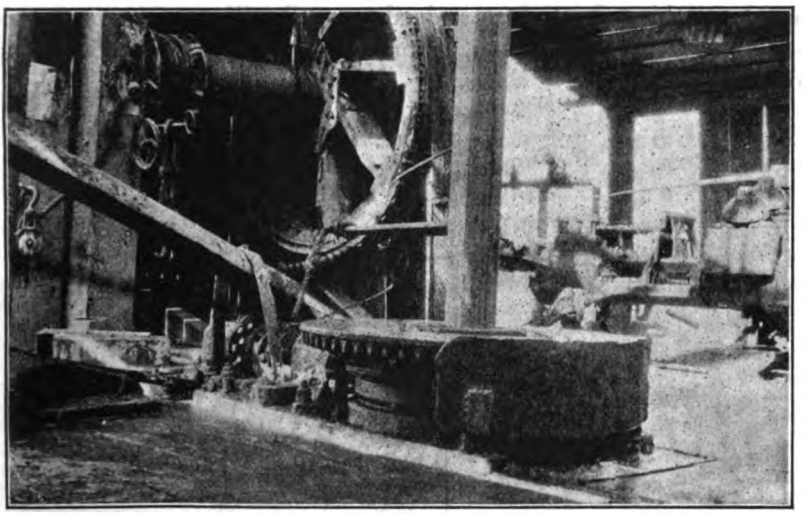

FIGURE 21.—Rotary table guard

The metal box safeguard shown in Figure 20 is made of one-quarter-inch steel, the sides and top of which are welded together. This guard fits snugly between the three bearings and has an oil hole

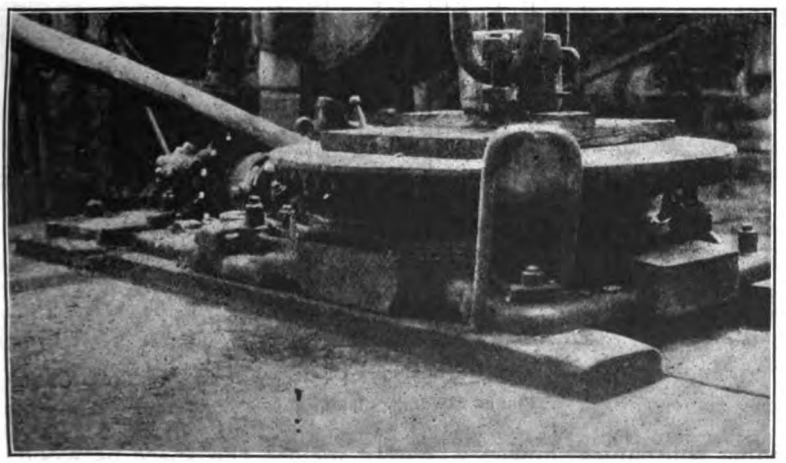

FIGURE 22.—Metal foot-brace for rotary table

drilled in its top at *a*. The bevel gears can, therefore, be oiled and the bearings adjusted without removing the guard.

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SAFEGUARDING THE ROTARY TABLE

The small number of accidents caused by the rotary table is gratifying though somewhat surprising. The casual visitor at a drilling well where the floor is so often muddy or wet and slippery would consider nothing short of a standard two-rail railing as a proper guard for a rotary table in motion. Fortunately, no such drastic precaution is necessary.

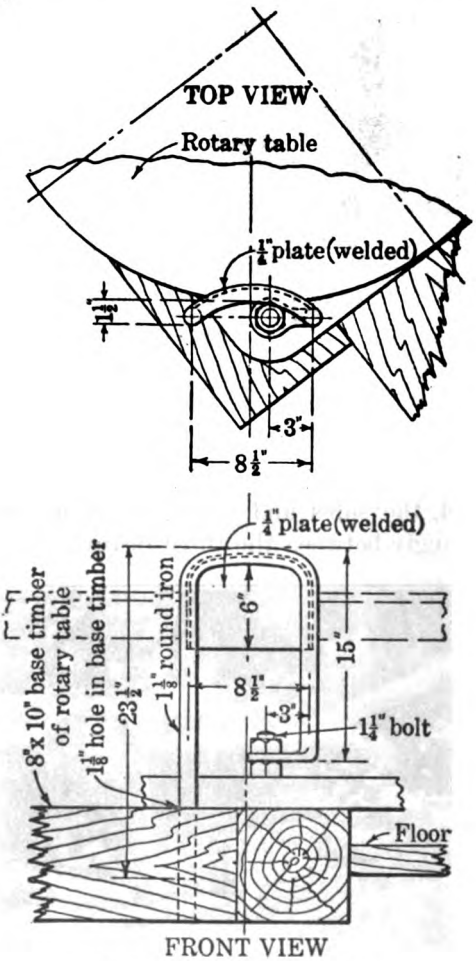

FIGURE 23.—Rotary table foot-brace

Some companies, however, partly inclose the space between the top of the gear table and the table base by a guard to prevent workmen from coming in contact with the teeth on the underside of the gear table or the sharp edge of the table. This guard, shown in Figure 21, is a steel plate one-quarter inch thick, bent around the table on the sides where the three rotary helpers stand.

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A combination safety and efficiency appliance is the foot rest or brace that enables a workman to place his foot squarely against an immovable object without danger of slipping when pulling drill pipe, tubing, or casing away from the center of the rotary table during breaking-down operations or when bringing them to the center of the table to make up a string of pipe. Figure 22 shows one very efficient type of foot brace; Figure 23 is a working drawing of this brace.

SAFEGUARDING THE END OF THE PINION SHAFT OF THE CHAIN-DRIVEN ROTARY

The outer end of the pinion shaft of a chain-driven rotary table should be guarded so that a workman's foot can not come into contact with the rapidly revolving pinion-shaft lock or the squared end of the pinion shaft. The very simple safeguard shown in Figure 24 is

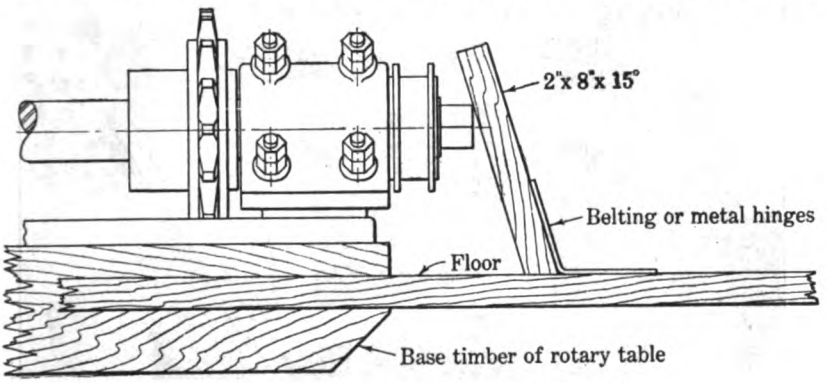

FIGURE 24.—Guard over outer end of rotary table pinion-shaft

used successfully by many operators. The hinges, which may be of metal or of scrap belting, hold the guard in place and allow it to be tipped back and out of the way in order to raise or lower the lock pawls or to insert the winged shaft wrench.

SAFEGUARDING THE SINGLE-CYLINDER DRILLING ENGINE

Unguarded engine flywheels are a menace to those working in their vicinity. In the oil fields a number of fatalities and many serious injuries have been caused by the unguarded flywheels of single-cylinder drilling engines. A great many of the accidents result from workmen treading on the spokes of the flywheel in order to turn the engine "off center"; and until some efficient device has been perfected and adopted by the oil industry to enable employees mechanically to throw the engine off center, accidents from this source will continue. Men can be trained, however, in the proper way to turn the flywheel over, so that when it suddenly starts revolving they

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will not get caught and be injured or killed. Many of the other accidents attributed to drilling-engine flywheels, however, could have been avoided by the installation of proper guards.

Figure 25 shows several ways in which to guard the flywheel of the single-cylinder drilling engine. This guard is built entirely of wood, 2 by 4 inch lumber for posts and 1 by 4 inch lumber for rails. The upper rail is 42 inches and the lower rail 18 inches above the floor. Note that the timber draw-works brace has been moved a safe distance (about 18 inches) from the side of the flywheel, so that danger of being caught between the brace or the railing and the flywheel does not exist. The gate is hinged so as to open from the

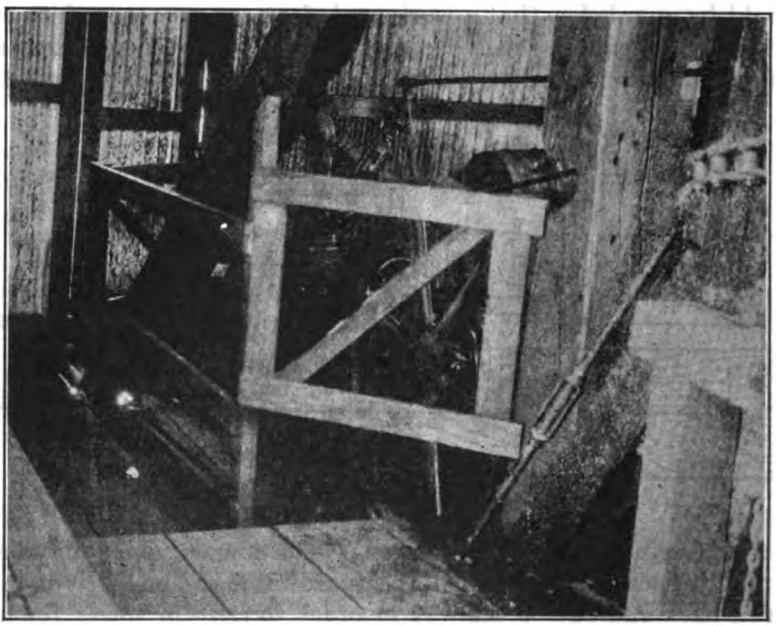

FIGURE 25.—Safety railing in front of the flywheel of a single-cylinder drilling engine

end nearest the draw works, which allows quick entrance if the flywheel must be moved off center.

Another type of steam-engine flywheel safeguard used at a drilling well (Figure 26) is locally known as the sliding-door type. It consists of a wooden frame with a galvanized corrugated iron filler. The guard is suspended in front of the flywheel from a 1-inch iron rod along which the door travels. Because of its closed construction, this guard may be hung close to the engine flywheel. When a man has to work on the flywheel or to "kick the engine off center" the door must be entirely moved out of the way so that he can not get caught between the guard and the flywheel of the engine.

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Because of quick starts, stops, and reversals in direction of rotation of the drilling-engine flywheel, the hub bolts often work loose, causing the spokes to crack and permitting the rim to burst. To prevent broken fragments of a bursting flywheel from striking the driller, who must stand directly in line with the flywheel, a buffer post 12 by 12 inches square is placed, as shown at *b* in Figure 26, between the draw works and the face of the flywheel. This precaution has prevented many injuries and is relatively inexpensive.

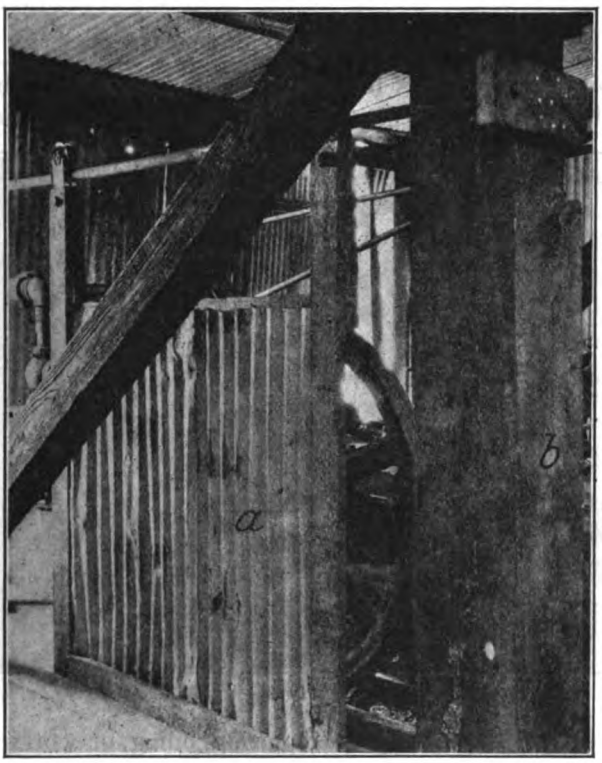

FIGURE 26.—Single-cylinder drilling-engine flywheel guard: *a*, Sliding-door type of flywheel guard; *b*, buffer-post flywheel guard

SAFEGUARDING THE TWIN-CYLINDER DRILLING ENGINE

The eccentrics and links of a twin-cylinder drilling engine should be guarded so that a breaking drive chain can not fly back and reverse the engine. Twin-cylinder engines when they leave the factory are equipped by the manufacturers with metal shields that completely house the eccentrics and links, but workmen at the well often take these off and fail to replace them. The engine drive-chain safeguards shown in Figures 9 and 10 have side plates of steel at the lower end which prevent a breaking chain from whipping sideways and interfering with the movement of the reciprocating parts and the reversing lever of the

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drilling engine. When guards of this description have been installed over the drive chain and engine sprocket, the separate link and eccentric guards can be discarded, and every safety requirement will have been met.

To safeguard the twin-cylinder drilling engine entirely, some companies build a standard two-rail railing (often of pipe in place of lumber) around the two sides and end of the engine. (Fig. 27.)

SAFETY SUGGESTIONS

USE OF STOP AND BLEEDER VALVES

Many oil-field accidents have been caused by steam that leaked past the throttle valve, accumulated in the steam chest, and turned

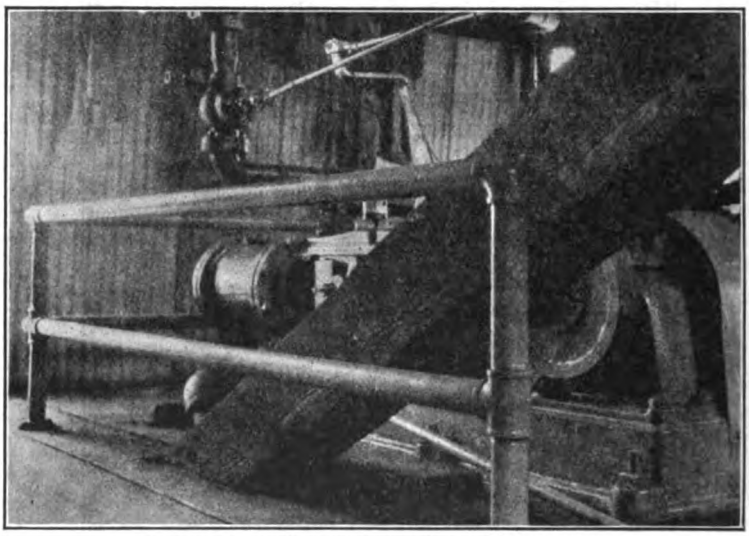

FIGURE 27.—Railing guard around twin drilling engine

the engine over while men were repairing, oiling, or working around the engine, chains, and draw-works machinery. To avoid similar accidents every drilling engine should be equipped with a stop valve installed in the steam line directly ahead of the throttle valve. In addition to this precaution the manifold of every twin-cylinder drilling engine, or the steam line between the throttle and the steam chest of single-cylinder engines, should be equipped with a bleeder valve large enough to exhaust the accumulated steam quickly—that is, not smaller than 1 inch.

No work should be done on the engine, chains, or draw-works machinery until the stop valve has been closed, the bleeder valve opened, and the engine securely blocked, or other provision has been made to prevent revolving and reciprocating parts from accidentally turning over.

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Figure 28 at *a* shows a bleeder valve designed to open automatically when the steam pressure in the manifold of the twin drilling engine, or in the steam chest of the single-cylinder drilling engine, falls to 5 pounds or less. This valve remains open as long as the throttle valve is closed and enough steam can not accumulate in the engine cylinders to "kick over" the engine accidentally. An ordinary leak in the throttle valve will not pass steam enough to build up a pressure in the cylinders sufficient to turn the engine over. In the photograph, the outlet pipe that conducts the steam and condensed water beneath the floor of the engine room has been disconnected. Steam that has escaped through the leaky throttle valve may be seen coming out of the relief valve. Aside from greater safety, this valve has another decided advantage. Through it the condensation in the manifold of the twin engine or the steam chest of the single-cylinder drilling engine drains every time the throttle valve is closed and only dry steam reaches the cylinders of the engines.

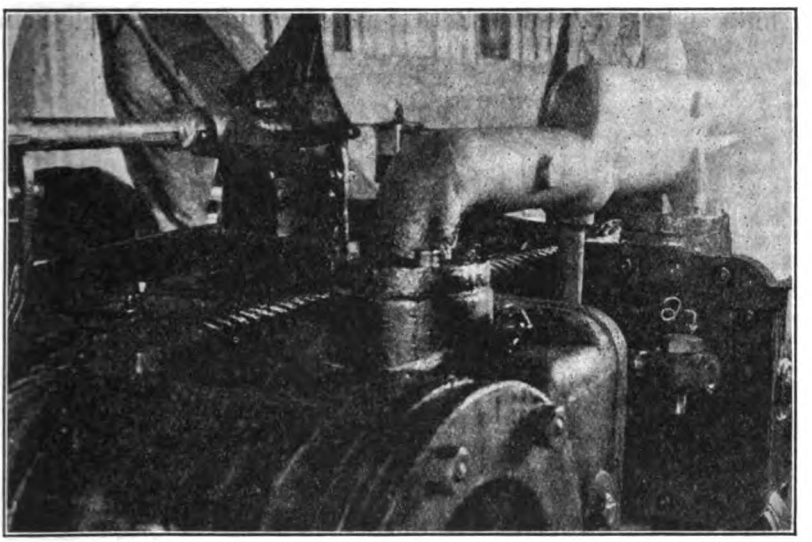

FIGURE 28.—Relief valve on twin drilling engine

The valve shown in detail in Figure 29 is a horizontal check valve fitted with a helical spring whose tension can be adjusted by the bolt through the body of the valve. This valve requires no attention after it has been adjusted to remain open when the steam pressure is 5 pounds or less.

FLYWHEEL ACCIDENTS

Many bursting flywheel accidents can be attributed directly to loose hub bolts or to overweighted rims. Hub bolts should be examined at frequent intervals and always kept tight. The flywheels

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should not be weighted with other than the balancing rims provided for that purpose, and then never in excess of capacities.

WORN CATHEADS

Catheads should never be used when grooves or ridges have been worn in them, as accidents caused by ropes sticking in the grooves and not slipping properly often occur. Every worn cathead is a menace to the safety of those working in the derrick.

SNAPPING AND BREAKING LINE GUARDS AT THE CATHEAD

Figure 30 shows two types of accident-prevention devices designed to reduce the number of accidents resulting in the loss of fingers, hands, arms, and legs of those who are caught in snapping and breaking lines and in catheads. Both types are suitable, though many

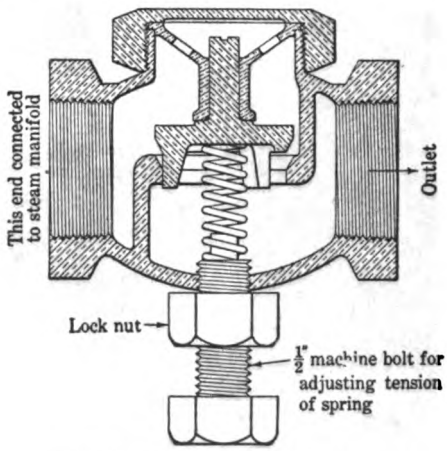

FIGURE 29.—Relief valve for drilling engines

operators prefer the long-slot type, as with it they can use the two drive-shaft bearing-box bolts in fastening the support to the draw-works post. During making-up or breaking-down operations the tong line should never be withdrawn from the support, and during the intervals when the stands are being raised or lowered the line should hang loosely from the U bolt.

PROTRUDING NAILS AND SPIKES

Nails and spikes driven into the draw-works timbers where workers are liable to come into contact with them are dangerous. Because sharp edges or projections can catch clothing or injure men so easily, care should be taken that such small exposures do not exist.

Using nails in place of cotter pins to hold the pins of the sprocket-chain links in place is likewise a minor violation of safety principles.

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As cotter pins the nails are unsatisfactory, more difficult to insert and clinch, wear quickly, and are a menace to safety.

USE OF LONG-SPOUT OILERS

Although many drillers shut down the machinery while oiling it, at times the machinery must be oiled when in motion. For both

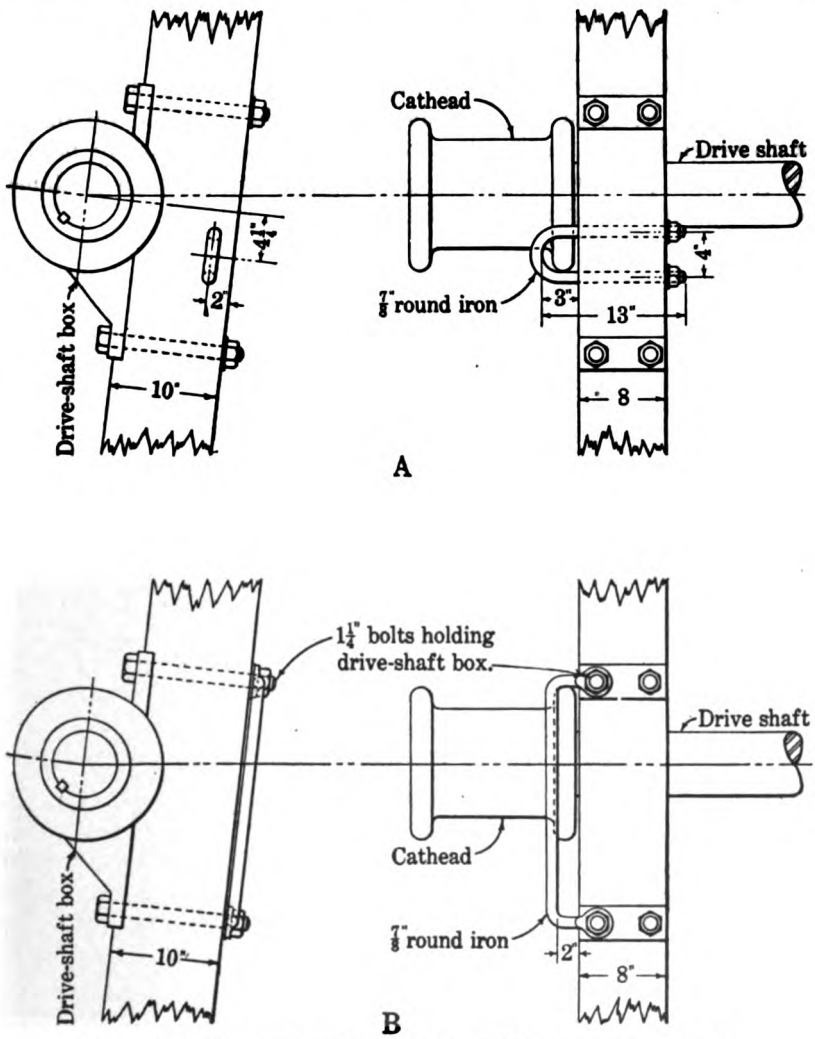

FIGURE 30.—Two types of guards for snapping and breaking line at the catheads

economy and safety every employer should provide oil cans or oilers equipped with long spouts, so that while a man oils machinery his hand and arm can remain a safe distance away from the moving parts. Gloves, especially those of the gauntlet type, should never be worn by a man oiling machinery.

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SECURE SAFEGUARDS

All safeguards should be securely fastened over the machinery that they guard. If they are hinged, care should be taken that the hinge bolt is not less than the size recommended and so fastened that vibration will not displace it. Wire spikes or the short pieces of wire so often used in place of the regular hinge bolts and cotter pins should not be tolerated. To use them is to invite disaster. For permanently fastening safeguards to the headboards or floor, use either lag screws or bolts. Two or three nails or spikes driven through the holes in the safeguard originally intended for one-half or five-eighths-inch lag screws or bolts can not possibly hold the safeguard in place when breaking chains or other machinery demand its maximum strength and holding power.

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